



The $Z \rightarrow b\bar{b}$ Search at CDF-II

*The 3rd generation as a
PROBE FOR NEW PHYSICS*



Research
Training Networks

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Summary

- ▶ Past Searches at CDF
- ▶ What can we learn from $Z \rightarrow b\bar{b}$?
- ▶ Can we do better things in Run-II?
- ▶ The Top Mass measurements
- ▶ A new trigger for $Z \rightarrow b\bar{b}$
- ▶ Projections to 2 fb^{-1}
- ▶ Extracting the b-jet energy scale
- ▶ Conclusions

Past Searches

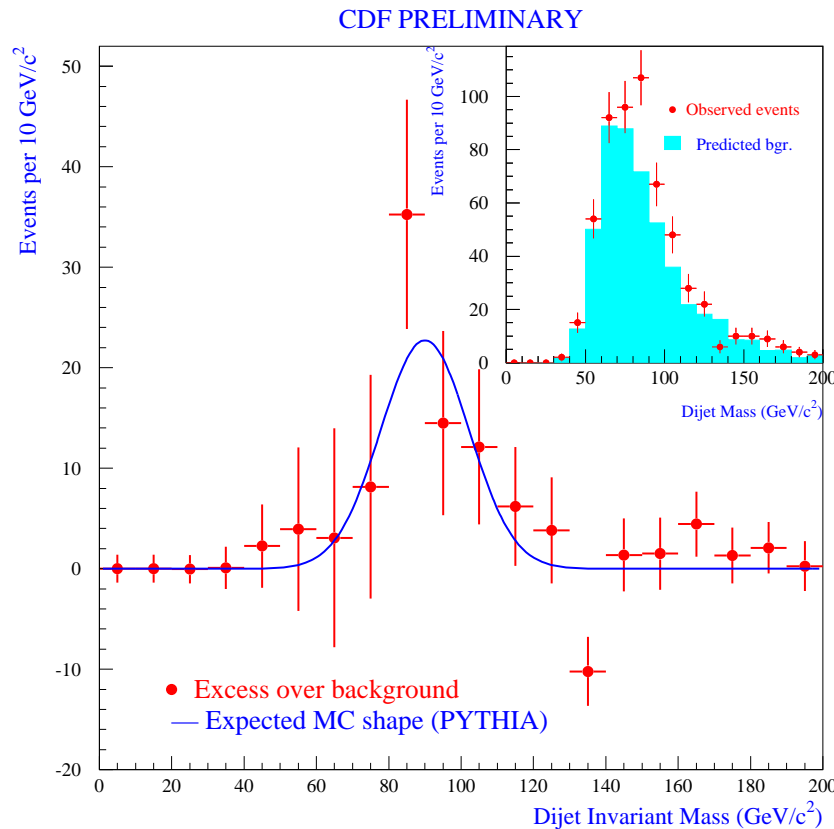


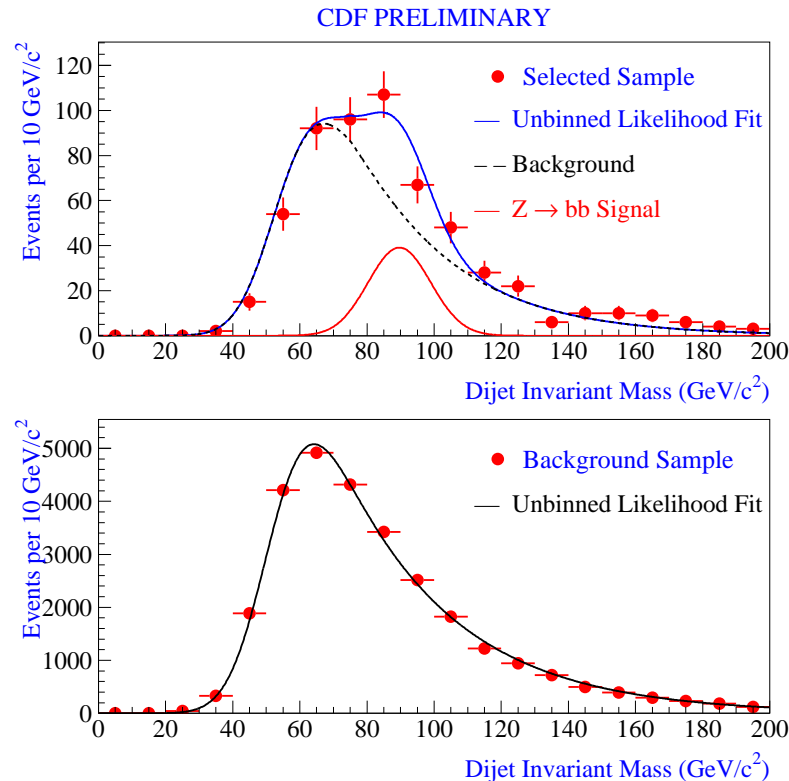
Fig. Results of the counting experiment
([hep-ex/9806022](https://arxiv.org/abs/hep-ex/9806022))

The $Z \rightarrow b\bar{b}$ process was for the **first** time isolated during the Run-I by the CDF-Collaboration.

Events were collected using a muon based trigger and selected requiring:

- 2 jets with $E_T \geq 10 \text{ GeV}$ tagged as coming from a b-quark decay;
- $\Delta\phi_{jj} > 3 \text{ rad}$;
- $\Sigma_3 E_T < 10 \text{ GeV}$.

Past Searches - cont'd

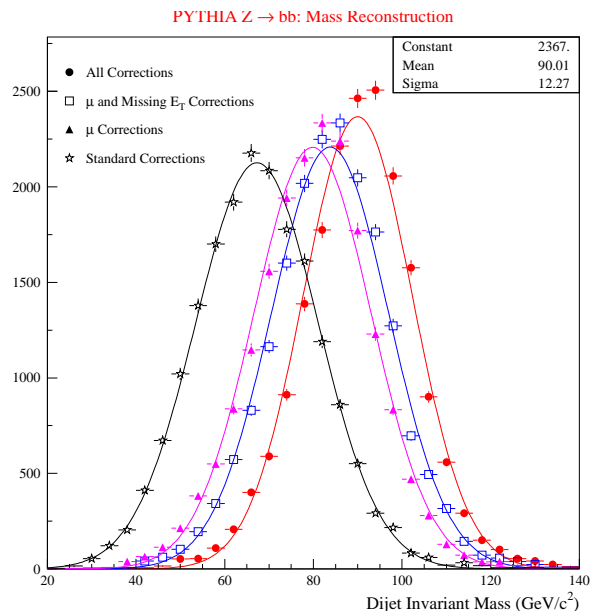


Another method to extract the amount of signal is that of performing an unbinned two component fit (signal + background shapes) to the dijet mass distribution. The number of events attributed to a $Z \rightarrow b\bar{b}$ signal in the region around 90 GeV was estimated to be:

$$N_Z = 91 \pm 30(stat.) \pm 16(syst.)$$

- ▶ The signal shape was extracted from a Monte Carlo template while
- ▶ the background shape was obtained from data events containing only one tagged jet.

What can we learn from $Z \rightarrow b\bar{b}$?



During Run-I, Monte Carlo based jet energy corrections (based on muon momentum, the \cancel{E}_T and the jet charged fraction) allowed to obtain a better resolution on the $Z \rightarrow b\bar{b}$ mass peak.

In Run-II, we can also determine jet corrections using the Z peak itself as a calibration tool. It is then possible to:

- ▶ test and tune b-specific **jet corrections**;
- ▶ extract the **b-jet energy scale** and its uncertainty.

This information can be used in different analyses involving events containing b-jets, such as:

- ▶ **Associated Higgs production.**
- ▶ **$t\bar{t}$ production.**

Why do b-jets require more attention?

While large samples of events with an high- P_t photon or a leptonic Z recoiling against an hadronic jet may give the possibility to determine the energy scale for the light quark jets,

the situation is different for b-jets because of:

- ▶ the very low cross section of processes with b-quark recoiling against photons or Z bosons.
- ▶ the presence of neutrino and leptons inside b-jets considerably alter the calorimetric response.

B-jets need an independent tuning!

Can we do better things during Run-II?

Asking this question requires some information about the upgrade of the experimental complex. So we can start asking **what is it new?**

The accelerator:

- 1.) The C.M energy: $\sqrt{s} = 2.0 \text{ TeV}$ instead of 1.8 TeV ,
- 2.) the Instantaneous Luminosity: $\mathcal{L}_{ist} \sim 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ ($\mathcal{L}_{ist} \sim 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$),

1.) + 2.) \rightarrow increase of the available statistics

CDF-II detector:

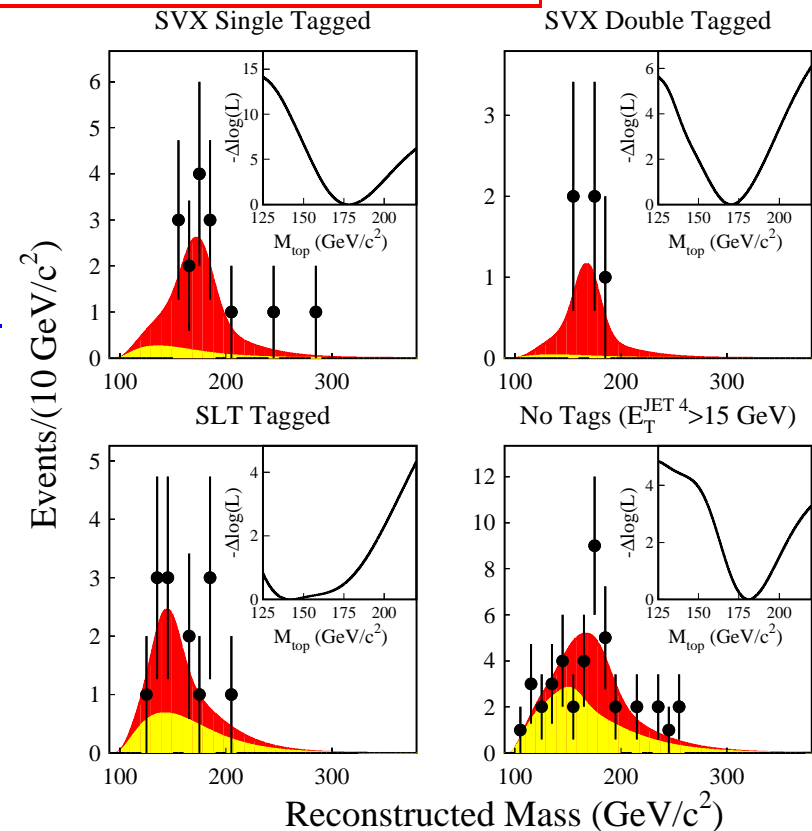
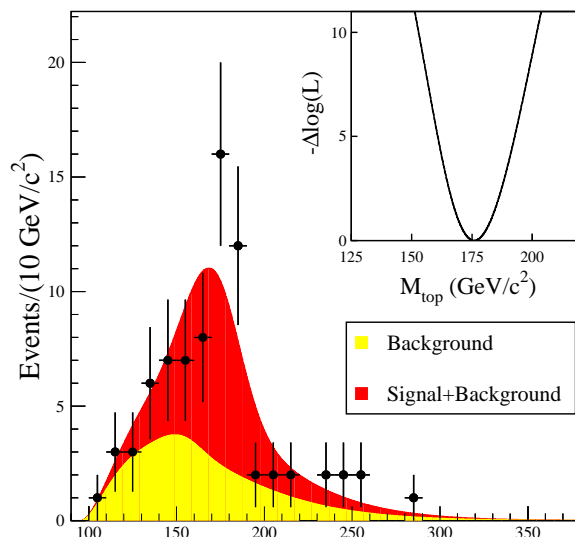
- 3.) New 7 layers silicon detector + new central tracking chamber
- 4.) New Plug calorimeters
- 5.) New silicon detector based trigger at work (SVT)

3.) + 4.) + 5.) \rightarrow more discriminating power
and increase of the accuracy of the measurement

The Top mass measurements - 1

During Run I, the single most precise technique for the top mass measurement was the one based on lepton+jets events collected by CDF.

Set	N_{obs}	$F_{bgr}(\%)$	M_t (GeV)
2 SVX	5	5 ± 3	170.1 ± 9.3
1 SVX	15	13 ± 5	178.0 ± 7.9
SLT	14	40 ± 9	142^{+33}_{-14}
4 jets	42	56 ± 15	181.0 ± 9.0

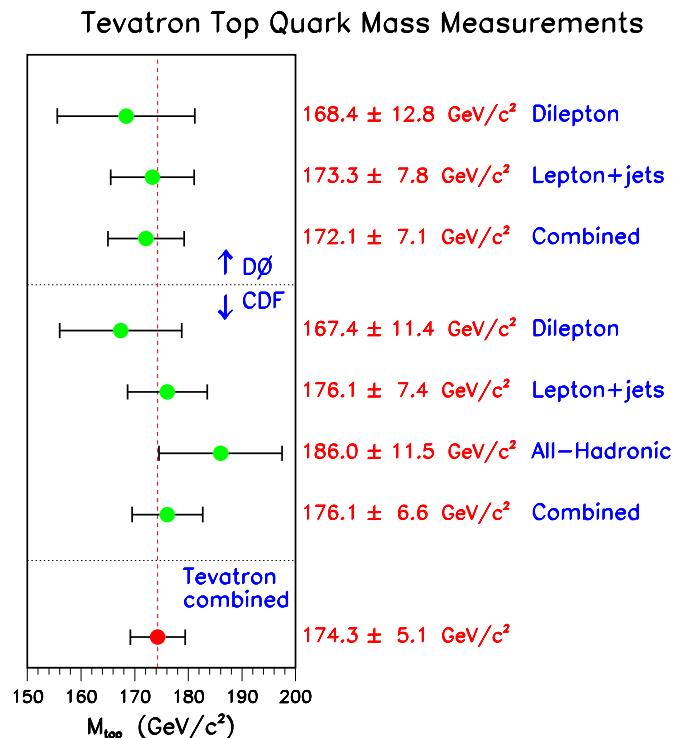


The final result from single lepton events

was $M_t = 176.1 \pm 5.1 \pm 5.3 \text{ GeV}$

(PRD 63, 32003 (2001)).

The Top mass - Systematics



Systematics on M_t [GeV/c^2]	Run I	Run II
Jet energy scale	4.4	2.2
Signal Model	2.6	0.4
MC generators	0.1	0.1
Background model	1.3	0.3
b-tagging bias	0.4	0.4
P.D.F.	0.3	0.3
Total	5.3	2.3

► The systematics even in Run I are larger than the statistical uncertainty.

- The uncertainty on the b-jet energy scale affected the top mass measurement as the dominant source of systematic error.
- We can use the high statistics available with Run II for a better determination of the b-jet energy scale using the $Z \rightarrow b\bar{b}$ channel. This is our main goal.

The new Trigger for $Z \rightarrow b\bar{b}$ events

During Run I, to see $Z \rightarrow b\bar{b}$ decays, we triggered on **MUONS**.

In Run II, with **SVT**, we trigger on the impact parameter of charged tracks.

This allows to collect large samples of unbiased b-enriched dijet events.

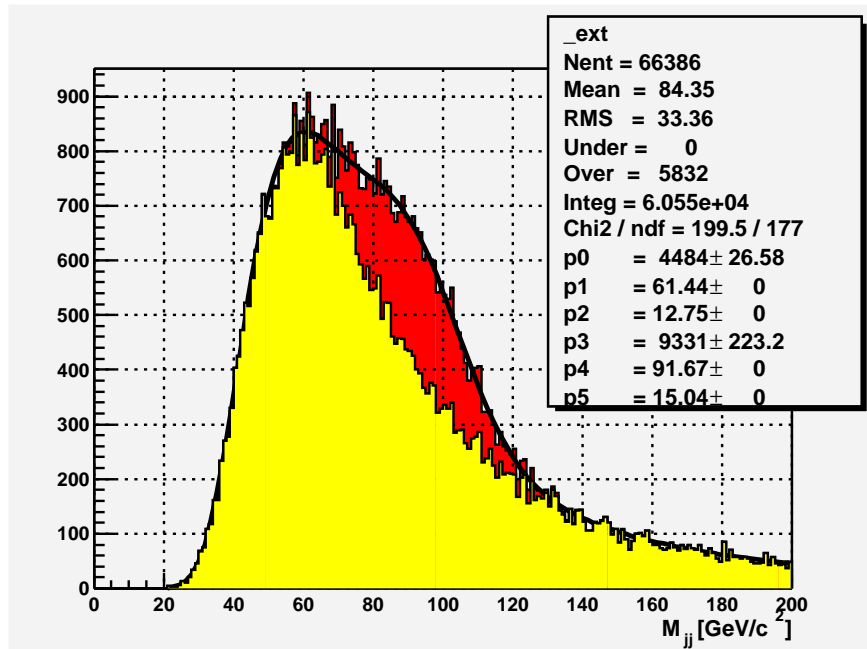
The trigger requirements develop through all the trigger system levels, but essentially, we select events containing: ►►

Z_BB Trigger ($\sigma_{trg} \sim 14 \text{ nb}$)

- 2 jets with $E_T > 10 \text{ GeV}$
- 1 trk with $P_T > 2.5 \text{ GeV}$
- 1 trk with $P_T > 3.5 \text{ GeV}$
- both tracks with $150 \mu\text{m} < |d_0| < 1 \text{ mm}$
- $\Delta\phi_{tt} > 150^\circ$

Efficiency on signal = $2.16 \pm 0.07\%$

Projections to 2 fb^{-1}



► Early data from Run II have confirmed the potential power of the SVT-based triggers in collecting heavy-flavour samples.

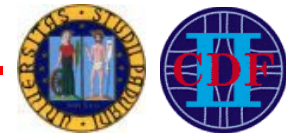
► On the offline side, b-jet tagging is to date under optimization but a development version is available to get first hint for analysis tools.

► First data collected with dedicated a $Z \rightarrow b\bar{b}$ trigger allow us to get some extrapolation on how, with the actual trigger running conditions, will appear the di-jet invariant mass. _____

The figure shows the result of the extrapolation by means of a pseudoexperiment technique. In the plot,

- the signal shape is obtained from Monte Carlo events,
- while the background one follows the single tag data behavior.

The amount of signal events is determined on the base of trigger efficiency, collected luminosity and predicted $Z \rightarrow b\bar{b}$ cross section ($\sim 1.2 \text{ nb}$) for Run-II.



Extracting the b-jet Energy scale

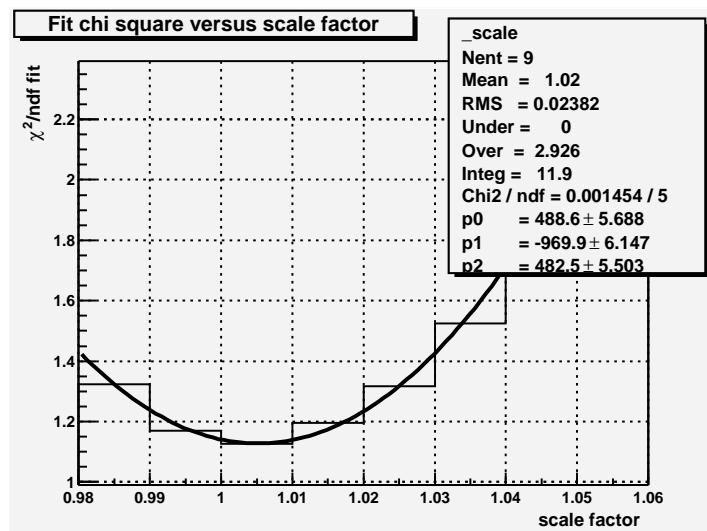
- ▶ Let us now **suppose to have the $Z \rightarrow b\bar{b}$ peak**, as shown in the previous slide.
- ▶ It is possible to **iterate the extrapolation procedure**, performing several pseudoexperiments.
- ▶ Let us try to **describe the signal with different MC template**, in which the **jet energy** is varied by means of multiplying for a **scaling factor**, we call **jet energy scale factor**.
- ▶ For each result of the pseudoexperiment, we can **fit the mass spectra** with the so obtained template for different values of the jet energy factor, **maintaining the same background shape**.
- ▶ A two component fit is performed with M_Z and its **width fixed to the MC template values**.
- ▶ Each fit will return its χ^2/ndf .
- ▶ In this way, we can **evaluate the fit quality** looking at its χ^2/ndf .

Extracting the b-jet Energy scale - cont'd

For a given pseudoexperiment,

the shape of the extrapolated data is in this way fitted for various values of the energy scale factor.

In the following, the χ^2/ndf distribution versus energy scale factor is shown.



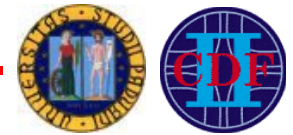
A polynomial fit return the value of the scale at which the χ^2/ndf is minimum.

A typical result is:

$$\text{scale factor} = 1.005 \pm 0.003$$

The error on the energy scale is determined as the difference between the scale factor values corresponding to a variation of the χ^2/ndf of one unit from the minimum.

We can iterate the procedure for N pseudo-experiments.



Conclusions

- ▶ The $Z \rightarrow b\bar{b}$ channel should be considered as a **milestone** for all future analyses involving the use of high- P_T b-jets
 - ▶ it provides the possibility of tuning and testing specific **b-jet energy corrections**;
 - ▶ as a calibration channel it can be used to determine the **b-jet energy scale** and its uncertainty.
- A $Z \rightarrow b\bar{b}$ -group was formed with the collaboration of **Padova, Chicago, Harvard** and **Berkeley**. Common tools were defined. Right now the group is working producing several MC events and testing offline packages.

See you at the Winter Conferences for first results!

Let us look at b-jets...

During Run II, CDF can identify secondary vertices inside jets in an extended range in pseudorapidity.

A new trigger system,

SVT,

is available for the

online identification

of hadronic events with

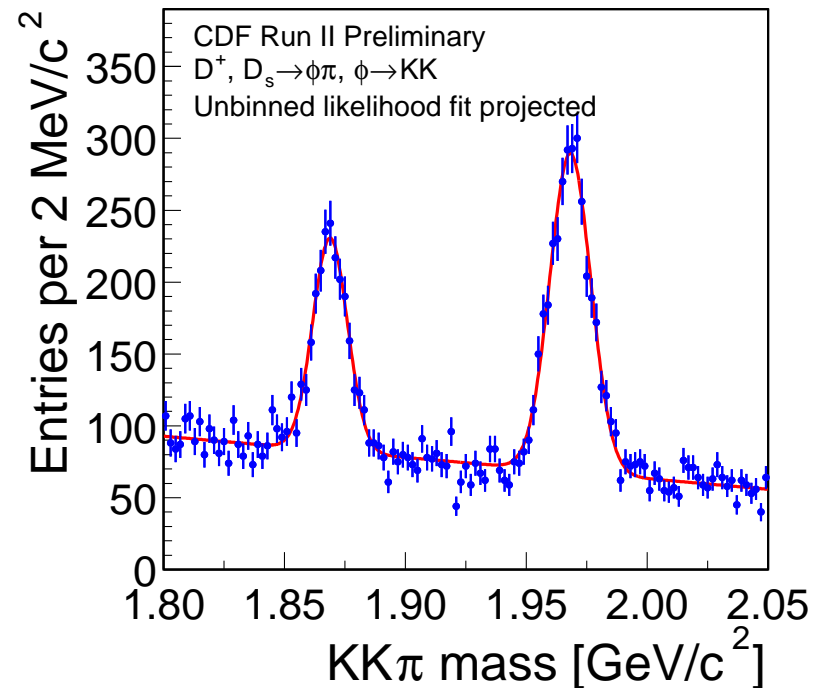
displaced tracks

with respect to the interaction point.

SVT allows measurements of P_T , ϕ and impact parameter d of charged tracks inside the region $|\eta| < 2$ with a resolution of $\sigma_d \sim 45 \mu m$.

$$m(D_s^\pm) - m(D^\pm) = 99.28 \pm 0.43 \pm 0.27 \text{ MeV}/c^2$$

(PDG 2002: $99.2 \pm 0.5 \text{ MeV}/c^2$)



With low statistics (11.6 pb^{-1}) CDF already produces its first physics results.

("SVT status and perspectives", Spinella, Menzione)

Definition of the impact parameter

